Welcome to the
NASA Applied Remote Sensing Training (ARSET)
Webinar Series

Introduction to Water Quality (WQ) Monitoring From Remote Sensing Measurements

Course Dates: November 18, November 25, and December 2, 2014
Time: 8 to 9 am Eastern US time

ARSET : Applied Remote SEnsing Training
A project of NASA Applied Sciences

Outline

- About this Course
- About ARSET
- Water Quality Monitoring
- Introduction to Remote Sensing and NASA Satellites/Sensors for Water Quality Monitoring

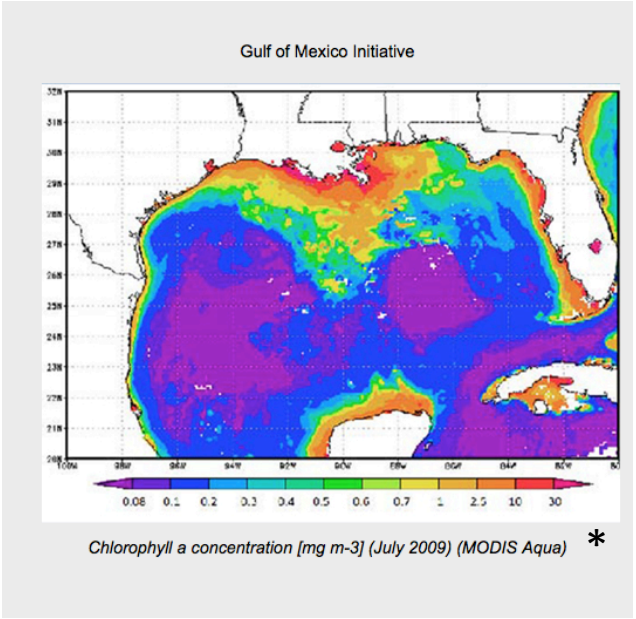
ARSET : Applied Remote SEnsing Training

Course Information

ARSET : Applied Remote SEnsing Training

Course Objective

- To introduce remote sensing data, access, analysis, and applications for water quality (WQ) monitoring in coastal oceans, estuaries, and in-land lakes.



Chlorophyll a concentration [mg m-3] (July 2009) (MODIS Aqua) *

This course will focus on surface water quality

*MODIS: The Moderate Resolution Imaging Spectroradiometer

Course Structure

- There will be three sessions in this course:
  November 18, November 25, and December 2, 2014
- There will be a homework assignment distributed after the second session
- A certificate will be awarded to participants who attend all three sessions and submit the completed homework assignment

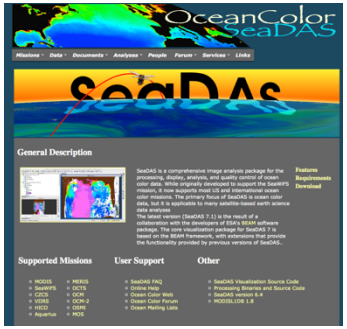
Course Outline

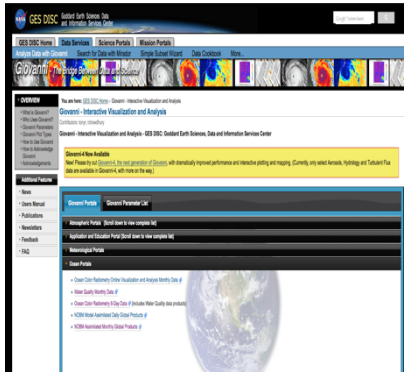
Week 1

Introduction to Remote Sensing of WQ

Week 2

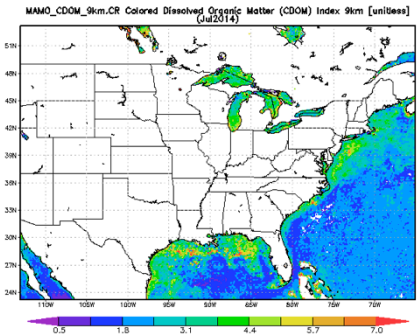
NASA WQ Data, Access, and Tools





Week 3

Overview of WQ Monitoring and
Case Studies of Monitoring WQ in Selected Water Bodies



Webinar Information

Speakers:

Amita Mehta (ARSET) amita.v.mehta@nasa.gov

Africa Flores (SERVIR) africa.flores@nasa.gov

Ana Prados (ARSET) Ana.I.Prados@nasa.gov

Guest Speaker:

Blake Schaeffer (Week -3) Schaeffer.Blake@epa.gov

ARSET : Applied Remote SEnsing Training

Webinar Information

Presentation URL: http://arset.gsfc.nasa.gov/webinar

Contact for requesting Certificate and more information about the course material

Marines Martins : marines.martins@ssaihq.com

Acknowledgment:

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ARSET : Applied Remote SEnsing Training

Applied Remote Sensing Training (ARSET)

NASA Earth Science
Applied Sciences Program

Earth Science Serving Society: Thematic Areas

Agricultural Efficiency

Air Quality

Climate

Disaster Management

Ecological Forecasting

Public Health

Water Resources

Weather

Applied Remote Sensing Training Program (ARSET)

GOAL:
Increase utilization of NASA observational and model data for decision-support

Online and hands-on courses:

- **Who:** policy makers, environmental managers, modelers and other professionals in the public and private sectors.
  Where: U.S and internationally
- **When**: throughout the year. Check websites.
- Do NOT require prior remote- sensing background.
- Presentations and hands-on guided computer exercises on how to access, interpret and use NASA satellite images for decision-support.

NASA Training for California Air Resources Board, Sacramento

Gradual Learning Approach

Webinars

Free – ideal for Managers

Assumes no prior knowledge of remote sensing

Gradual Learning Approach

Webinars

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Hands-on Training

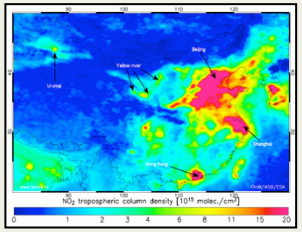
Basic and Advanced

Focused on a specific application/problem: for example products and tools for flooding applications in Latin America

Applied Remote Sensing Training Program (ARSET)

Health (Air Quality)

Nitrogen Dioxide over China

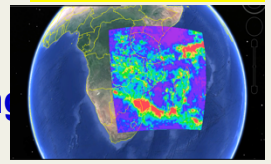


- 2008 – present
- 26 Trainings
- 900+ end-users
- Analysis of dust, fires and urban air pollution.
- Long range transport of pollutants
- Satellite and regional air quality model inter-comparisons.
- Support for air quality forecasting and exceptional event analysis

Water Resources and Flood Monitoring

- April 2011 – present
- 9 Trainings
- 600+ end-users
- Flood/Drought monitoring
- Severe weather and precipitation
- Watershed management
- Climate impacts on water resources
- Snow/ice monitoring
- Evapotranspiration (ET), ground water, soil moisture, and runoff.

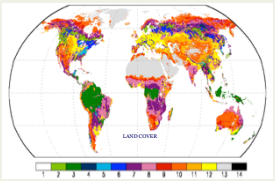
Satellite derived precipitation



Inundation mapping

Land Use/Change and Ecology

- Since May 2014
- GIS applications
- Land use/change
- Vegetation indices
- Fire products



Land Cover

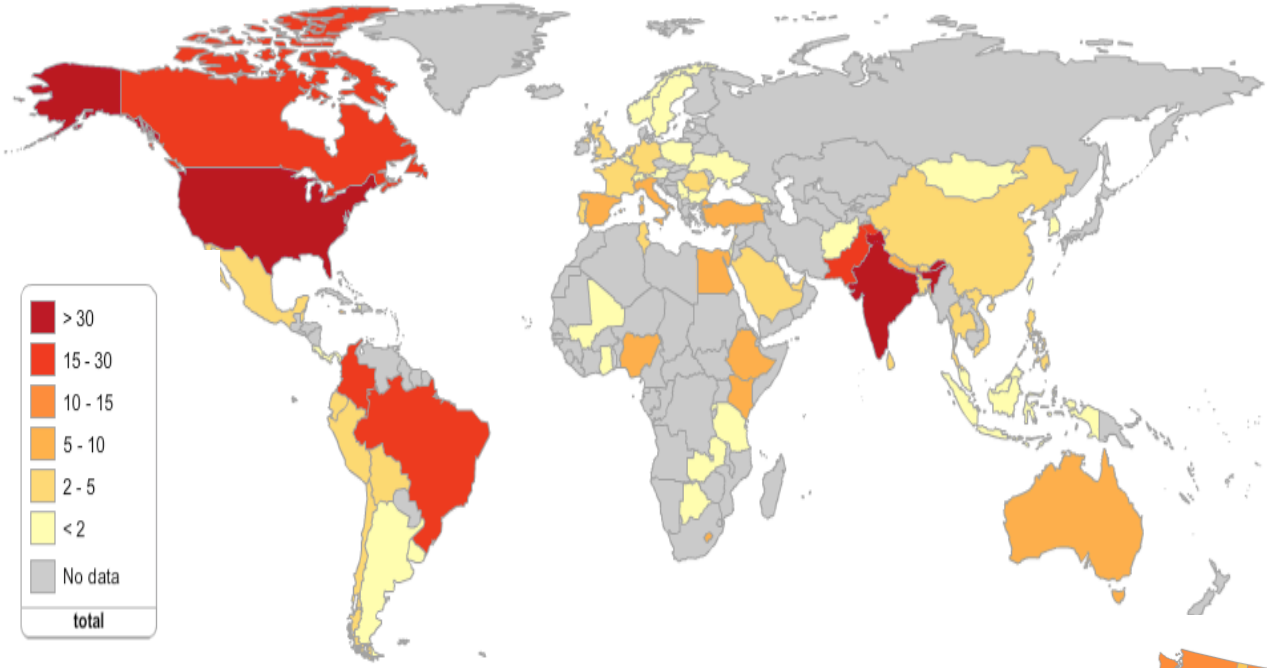
Train the Trainers (Starting in 2015)

- Courses and guidance on how to design and develop, *YOUR OWN* online and/or computer based remote sensing training
- How to develop effective presentations and exercises.

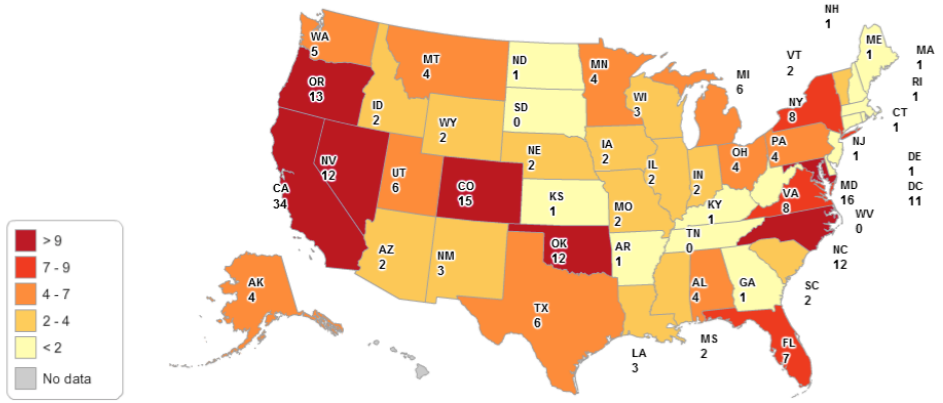
ARSET: 2009 – 2013

1800+ End-users Reached

500+ Organizations



Number of participating organizations per country: Air Quality, Water Resources, Flood Monitoring.



ARSET Training:
Water Resources/Flooding

Hands-on Courses:

- Cartagena, Colombia, November 2011, Precipitation and Flooding
- University of Oklahoma, National Weather Center, June 2012, Water Resources
- World Bank, DC, March 2013, flooding Applications

Online Courses:

Fall 2012 : Precipitation/Flooding/Drought

Spring 2013 and Winter 2014: Snow Products

Fall 2013: Water Resources Management

Fall 2013: Flood Monitoring

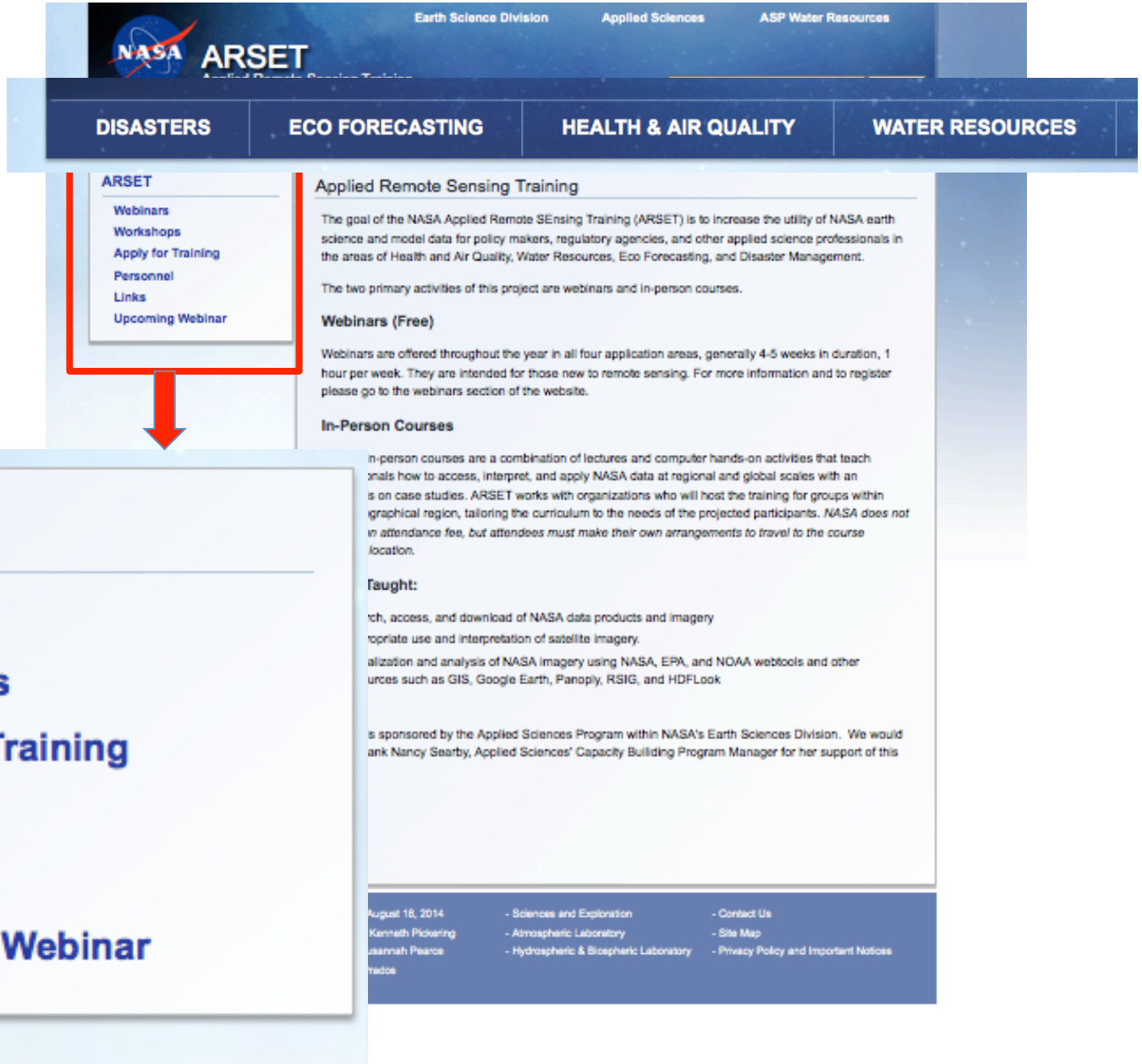
Presentation and Data Demonstration:

- USAID GeoCenter, Va, February 16, 2014, NASA Data for Water Resources and Disaster Management

Attendees of the NASA water resources training at the University of Oklahoma on June 19-20, with course instructors Amita Mehta and Ana Prados. Preliminary end-user feedback included a) interest in follow-on advanced/online courses and b) additional topics in land products, e.g. ET and Landsat.

ARSET Web Page

http://arset.gsfc.nasa.gov



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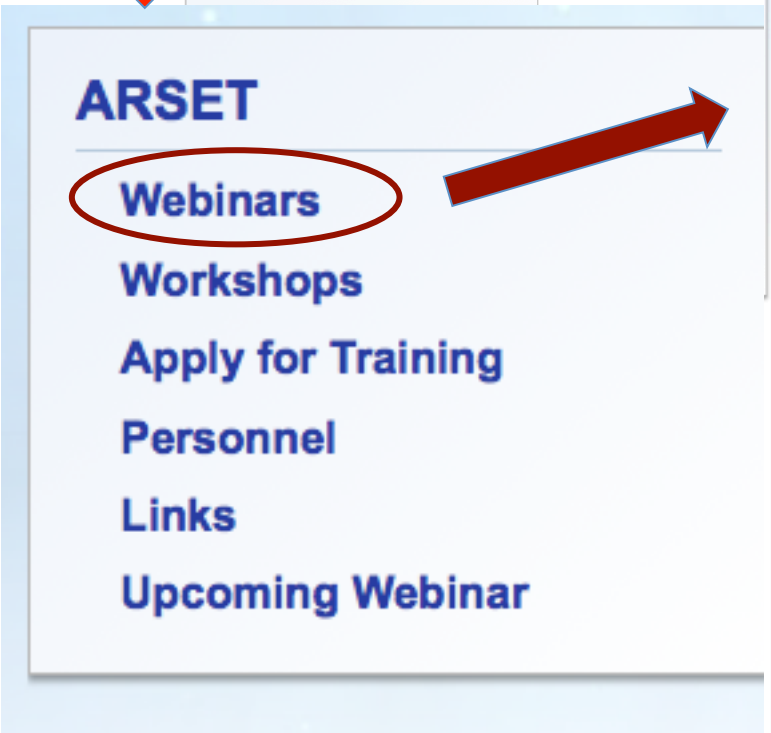


Webinars

Water Quality Monitoring Using Remote Sensing Measurements

Tuesday, November 18, 2014 to Tuesday, December 2, 2014

Course-I: 8-9 AM, Course-II: 1-2 PM, Course-III: 10-11 AM (Eastern US time)
Application Area: **Water Resources**
Keywords: **Satellite Imagery, Tools**
Instruments: **Aqua, Landsat, MODIS, Terra, VIIRS**

Read more

NASA Remote Sensing for Land Management

Monday, November 3, 2014 to Monday, December 1, 2014

12 PM - 1 PM Eastern US Time
Application Area: **Ecoforecasting**
Keywords: **Satellite Imagery, Tools**
Instruments: **Aqua, Landsat, Terra**

Read more

Introduction to NASA Earth Science Data Products, Portals, and Tools

Tuesday, September 16, 2014 to Tuesday, October 14, 2014

Tuesdays (5 one-hour sessions), 8-9 AM U.S. Eastern Standard Time (13 PM UTC)
Application Area: **Airquality, Disasters, Ecoforecasting, Water Resources**
Keywords: **Satellite Imagery, Tools**
Instruments: **Aqua, Landsat, Terra, TRMM**

Read more

Apply for a Training on ARSET Web Page

http://arset.gsfc.nasa.gov

Apply for Training

The NASA Applied Remote Sensing Training Program provides webinars and in-person courses. The goal of these training activities is to build the capability and skills to utilize NASA earth science observations and model data for environmental management and decision-support. Courses are primarly intended for applied science professionals and decision makders from local, state, federal agencies, NGOS, and the private sector. ARSET also offers a Train the Trainers program, which is recommended for establishing or growing your organizations' capacity in applied remote sensing.

ARSET trainings are NOT designed for research but for operational and application driven organizations.

To apply for a training email Ana Prados at **Ana.I.Prados@nasa.gov**

The program offers four types of courses. For in-person courses, applicants must provide a computer laboratory or similar facility.

1. Overview webinar course: held over a period of 4-5 weeks, 1 hour per week
2. Basic hands-on: In person applied remote sensing course for those new to remote sensing. Generally 2-3 days in length held. It is highly recommended that attendees first take the webinar course.
3. Advanced hands-on: In person applied remote sensing course that builds the skills to use NASA data for a specific environmental management problem. Intended for those who have already taken the basic course or have previous experience using NASA data and resources. Generally 1-2 days in length.
4. Train the Trainers: In person applied remote sensing course intended for existing remote sensing/geospatial trainers within the organization/institution/agency.

For information on upcoming courses and program updates sign up to the listserv

https://lists.nasa.gov/mailman/listinfo/arset

Week 1 Agenda

Introduction to Remote Sensing of WQ Monitoring

- *What does WQ mean?*
- *Remote Sensing of WQ: Overview of Remote Sensing, Advantages and Limitations*
- *Satellites/Sensors for WQ monitoring*
- *Examples of Remote Sensing of WQ*

Water Quality

How to monitor WQ?

Why is it important?

Water Quality

- WQ is a measure of the suitability of water for a particular use based on its physical, chemical, biological properties

- A number of quantities or **parameters** are used to define water properties and to assess water quality

Water Properties and Parameters

Water Quality is decided by the following water properties:

Physical Properties: Color, Temperature, Density, Heat Capacity, Turbidity, Suspended Sediment

Chemical Properties: pH, Salinity, Dissolved Oxygen, Conductivity, Hardness

Biological Properties: Phytoplankton/Algal Bloom (chlorophyll-*a),* Microorganisms, Colored Dissolved Organic Matter

In the U.S., the Environmental Protection Agency (EPA) is responsible for establishing the WQ standards for different uses. Information about regional/local water quality in the US can be obtained from:

http://www.epa.gov/safewater http://water.usgs.gov/nawqa

Water Quality – Why is it Important?

WQ is critical for human and ecosystems health and has economic implications

Is this water -

- safe for drinking?
- safe for swimming?
- safe for fish and other aquatic life forms in streams, lakes, and coastal oceans?
- safe for crop irrigation?

WQ in streams, lakes, and oceanic coastal zones is affected by natural factors and human activities

Natural Sources of Water Pollution :
Rainfall, Snow Melt and Run off
Dissolved solids (salts, minerals), Nutrients (Nitrogen Phosphorous, Dissolved Oxygen),

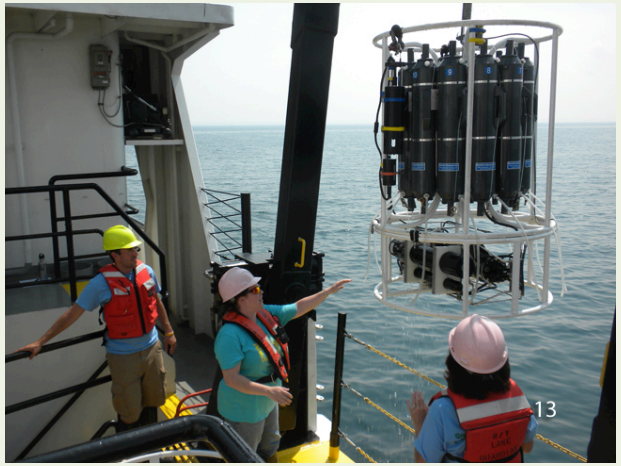
Human Sources of Water Pollution:
Urbanization, Industries, Farming, Mining, Fossil-fuel/ Gasoline, Sewage Discharge and Animal Waste
Nutrients, Chemicals, Metals, Pathogens

- Excess nutrients carried to streams and lakes encourage growth of algae, which leads to low oxygen in the water and may result in the destruction of aquatic life

Water Quality Measurements

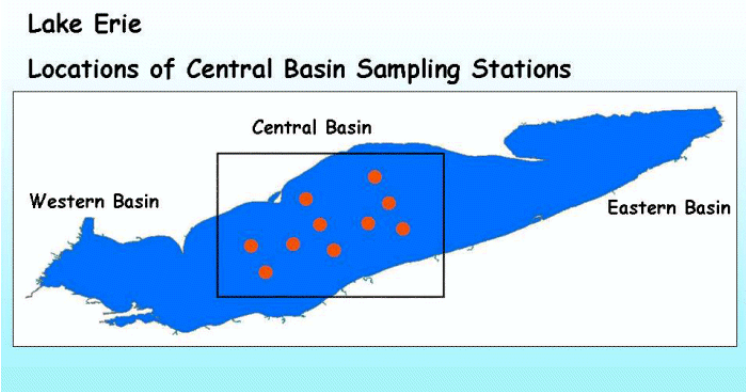
In the US, ***in situ*** *measurements and lab analysis to monitor these parameters in streams, lakes, and estuaries are conducted by:*

Environmental Protection agency (EPA)	http://water.epa.gov
US Geological Survey (USGS)	http://water.usgs.gov/owq/
National Oceanic -	http://www.nmfs.noaa.gov/
-and Atmospheric Administration (NOAA)	http://www.nerrs.noaa.gov



Limitations of *in situ* measurements

- Limited sample collection – not representative of entire water body
- Periodic sample collection may not capture daily, monthly, or seasonal water quality changes
- Labor intensive and expensive



http://epa.gov/greatlakes/monitoring/

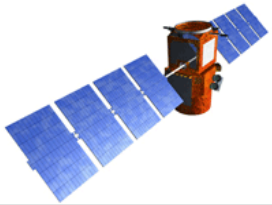
NASA earth observing satellites provide large, continuous spatial coverage from multi-year observations that are used to derive several of the WQ parameters

Physical Properties: Color, Temperature, Density, Heat Capacity, Turbidity, Suspended Sediment

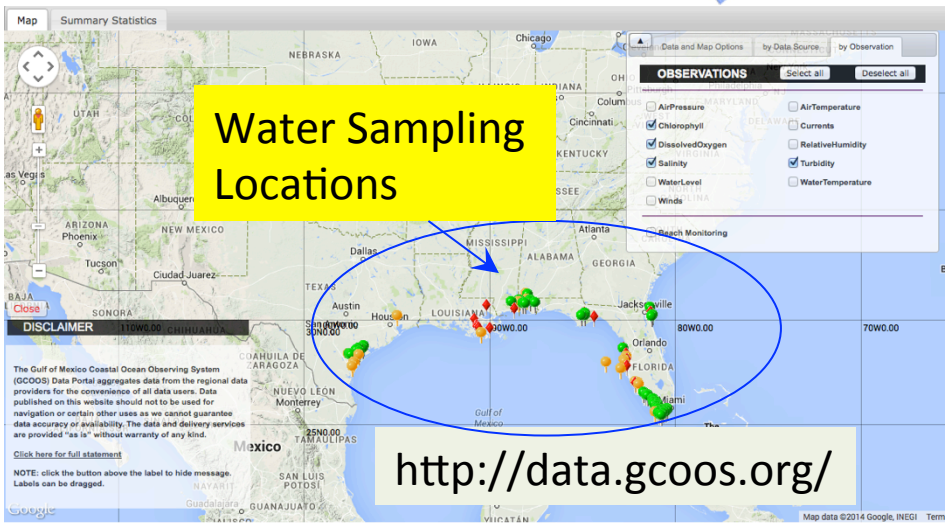
Chemical Properties: pH, Salinity, Dissolved Oxygen, Conductivity, Hardness

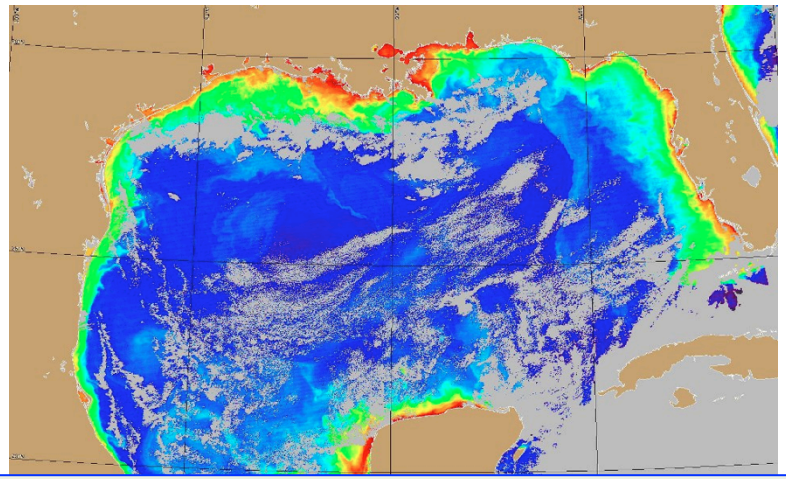
Biological Properties: Algal Bloom, Microorganisms, Colored Dissolved Organic Matter

Why use Remote Sensing for WQ Monitoring?



- Provides information where there are no surface-based measurements available and augments where they are
- Provides global/near-global coverage with consistent observations
- Provides continuous coverage in comparison to point measurements





MODIS Aqua satellite image from October 23, 2011, showing areas of elevated chlorophyll a (in red and orange)

Remote Sensing Observations

What is remote sensing?

How is it used for WQ Monitoring?

What is Remote Sensing?

Measurement of a quantity associated with an object by a device not in direct contact with the object

- Platform depends on application
- What information? how much detail?
- How frequent

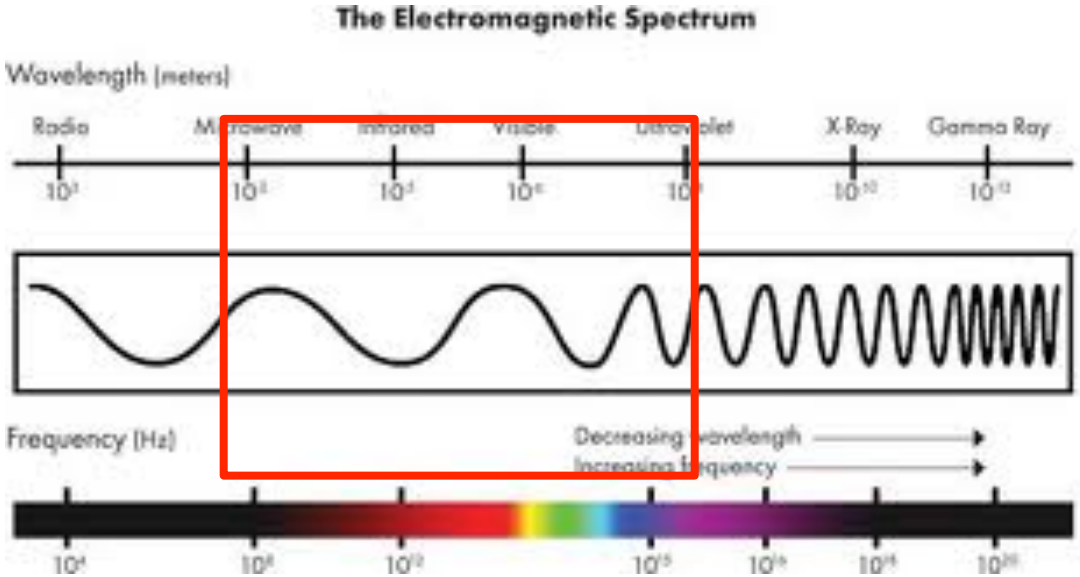
What is Satellite Remote Sensing?

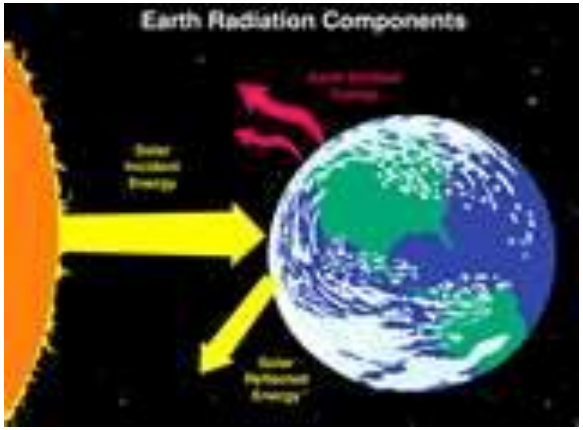
Measuring properties of the earth-atmosphere system from space

Satellites carry instruments or sensors which **measure electromagnetic radiation** coming from the earth-atmosphere system

Earth-Ocean-Land-Atmosphere System :

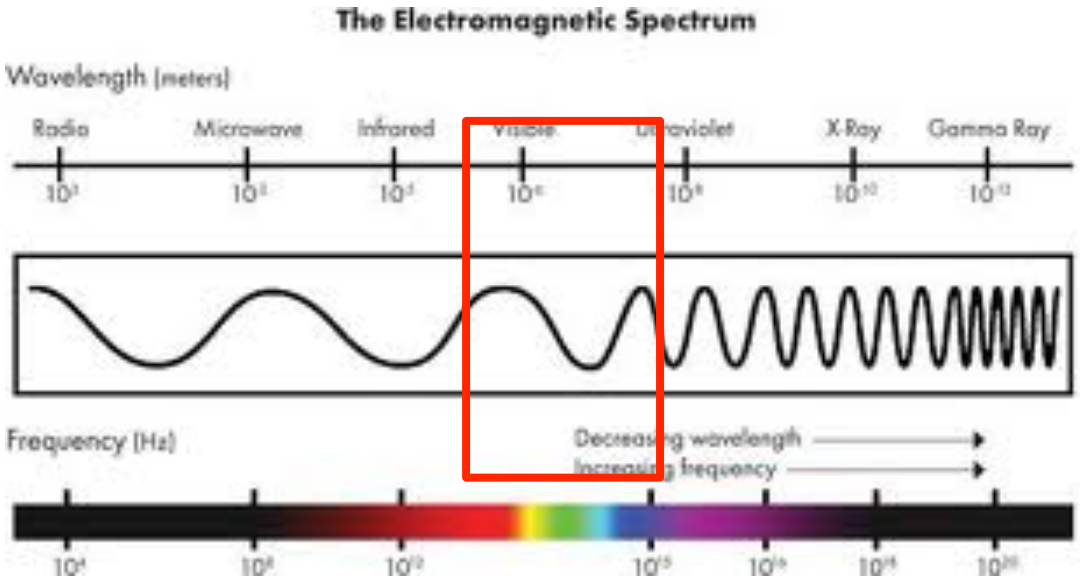
- reflects solar radiation back to space
- emits Infrared radiation and Microwave radiation to space

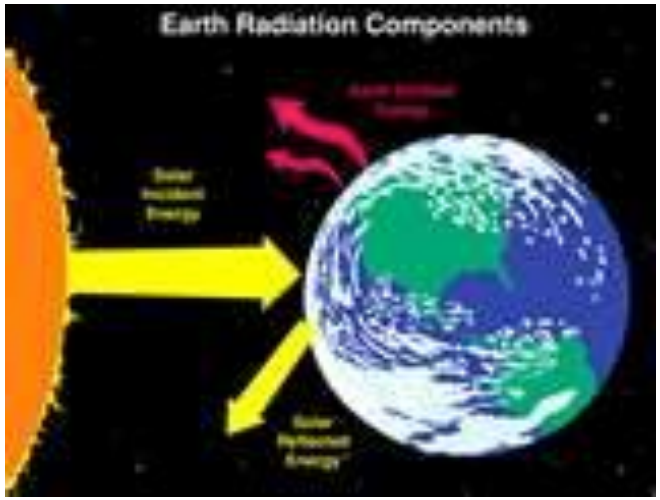




For Remote Sensing of Water Quality :

Reflected solar radiation back to space and emitted thermal Infrared radiation are used



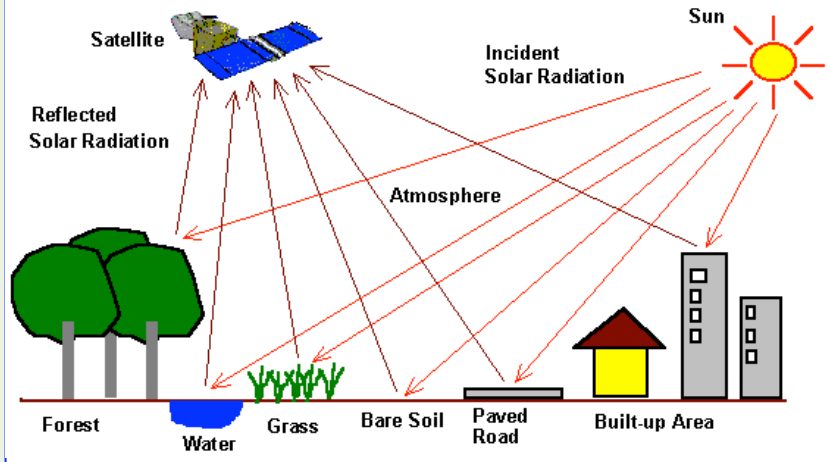


Remote Sensing of Water Quality Parameters

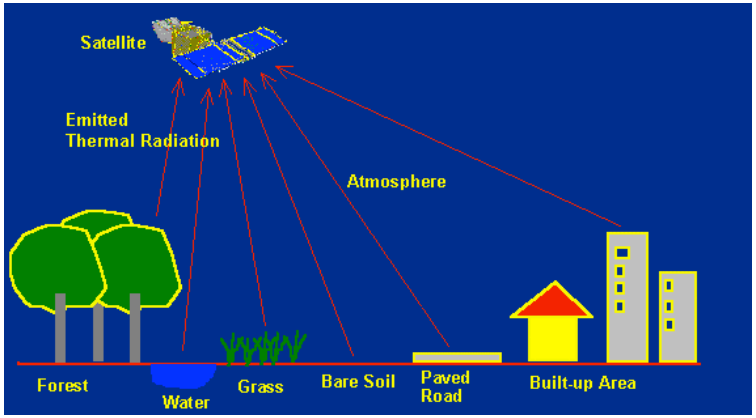
- Reflected solar radiation and emitted thermal radiation are measured by **satellite sensors** to detect water properties used for water quality assessment

- Suspended sediments, algae, Dissolved Organic Matter, oils, plants, change the energy spectra of the reflected/emitting radiation from surface waters and can be derived from remote sensing measurements

- Most chemicals and pathogens that do not directly affect or change the spectral or thermal properties of surface waters – can be inferred from other WQ parameters



Every surface has its own spectral signature



Water Quality Remote Sensing Techniques

- Qualitative interpretation of satellite images in various spectral bands which change with changing water quality

- Quantitative estimates of water quality parameters by using algorithms -- developed mainly by statistically relating satellite data and in situ measurements

From Environment Canada

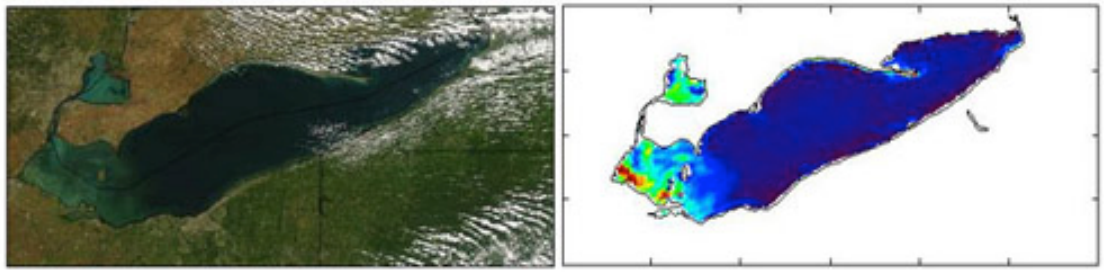


Figure 2: MODIS True Colour composite and derived total suspended particulate matter in Lake Erie.

http://www.ec.gc.ca

Satellite Remote Sensing Basics

Satellite Sensors

Passive remote sensors

measure radiant energy

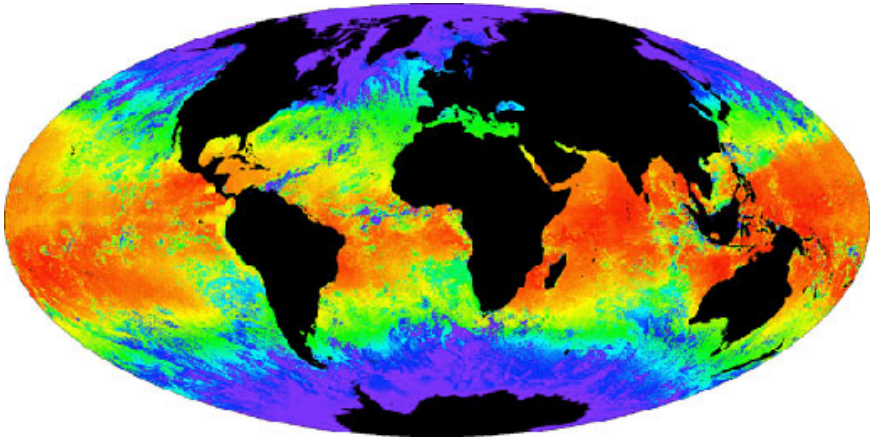
Reflected or emitted by the earth-atmosphere System

Radiant energy is converted to bio-geophysical quantities such as temperature, precipitation, soil moisture, chlorophyll-a

Examples:

MODIS, Landsat TM and ETM+

MODIS



This map of sea surface temperatures was produced using MODIS data on the Terra satellite. The red pixels show warmer surface temperatures, while yellow and green are middle values, and blue represents cold water. Credit: NASA GSFC

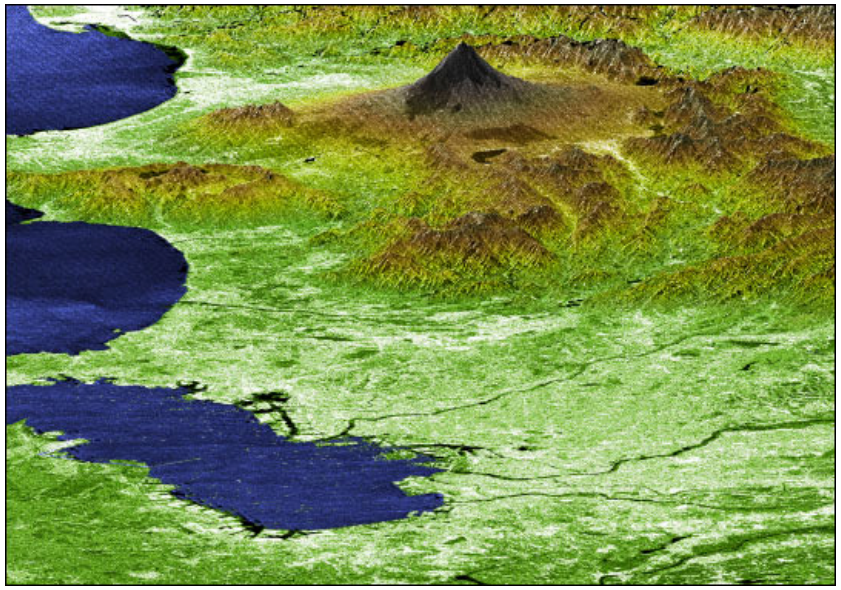
Satellite Sensors

Active remote sensors
'throw' beams of radiation
on the earth-atmosphere
system and measure
'back-scattered' radiation

The back-scattered
radiation is converted to
geophysical quantities

Examples: Radar, LIDAR

SRTM



Japan's Mt. Fuji presents a beautiful backdrop for the city of Tokyo in this perspective view generated using data from the **Shuttle Radar Topography Mission (SRTM).**
http://earthobservatory.nasa.gov/IOTD/

Spatial and Temporal Resolution of Satellite Measurements

Depends on the satellite orbit configuration and sensor design

- **Spatial Resolution:**

  Decided by its pixel size -- pixel is the smallest unit measured by a sensor

- **Spatial Coverage:**

  The geographical area covered by a satellite

- **Temporal resolution:**

  How frequently a satellite observes the same area of the earth

- **Temporal Coverage:**

  Time span or life-time of a satellite for which measurements are available

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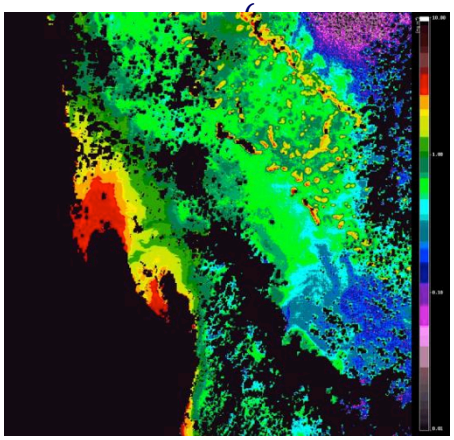
Spatial Resolution: Varies with satellite/sensor

Landsat-7 Image of Niger River Delta

Spatial resolution: 30 m

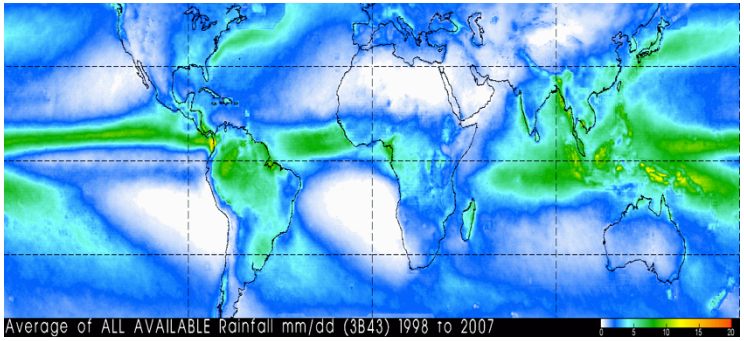
Chlorophyll from Terra/MODIS:

Spatial resolution: 1 km



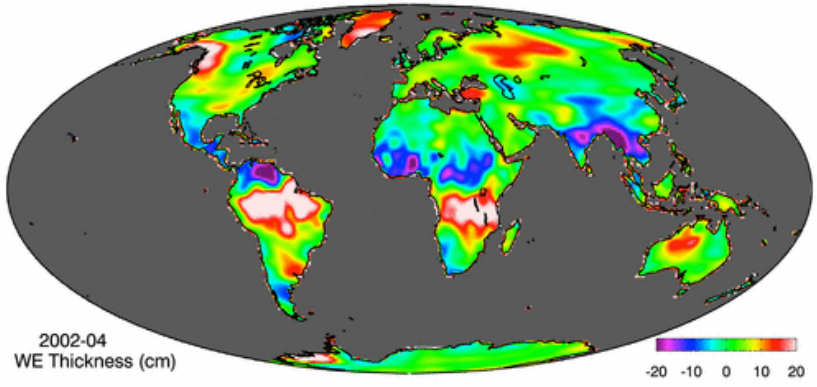
TRMM and Multi-satellite Rainrate

Spatial resolution: 25 km



Terrestrial Water Storage Variations from GRACE: Spatial resolution: ~100 km or coarser

(Courtesy: Matt Rodell, NASA-GSFC)



Spatial Coverage and Temporal Resolution of Satellite Measurements

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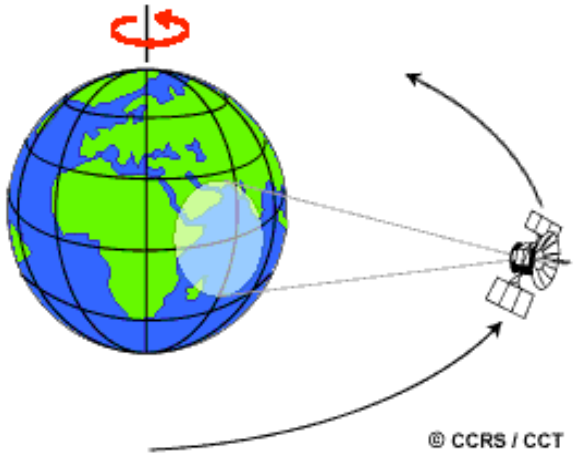
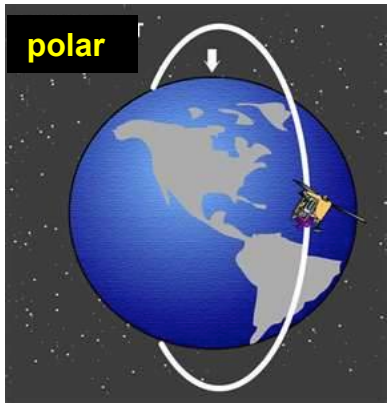
Types of Satellite Orbits

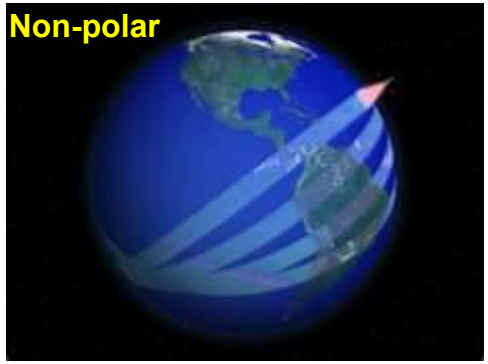
Geostationary orbit



Satellite is at ~36,000 km above earth at equator. Same rotation period as earth's. Appears 'fixed' in space.

Low Earth Orbit (LEO)





Circular orbit constantly moving relative to the Earth at 160-2000 km. Can be in Polar or non-polar orbit

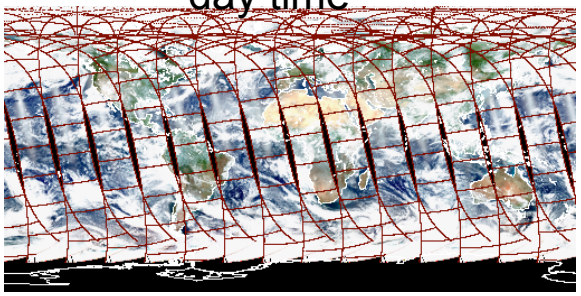
Spatial Coverage and Temporal Resolution

Polar orbiting satellites: global coverage - but one to two or less measurements per day per sensor. Orbital gaps present. Larger Swath size, higher the temporal resolution.

Non-Polar orbiting satellites: Less than one per day. Non-global coverage. Orbital gaps present. Larger Swath size, higher the temporal resolution.

Geostationary satellites: multiple observations per day, but limited spatial coverage, more than one satellite needed for global coverage.

Aqua ("ascending" orbit) day time



TRMM Image

GOES Image

Temporal Resolution

Most satellites used for WQ remote sensing are Sun synchronous, polar orbiting satellites with less than 1 to 2 observation per day

Aqua
Landsat
Terra
EO-1[+]
Suomi-NPP[*]

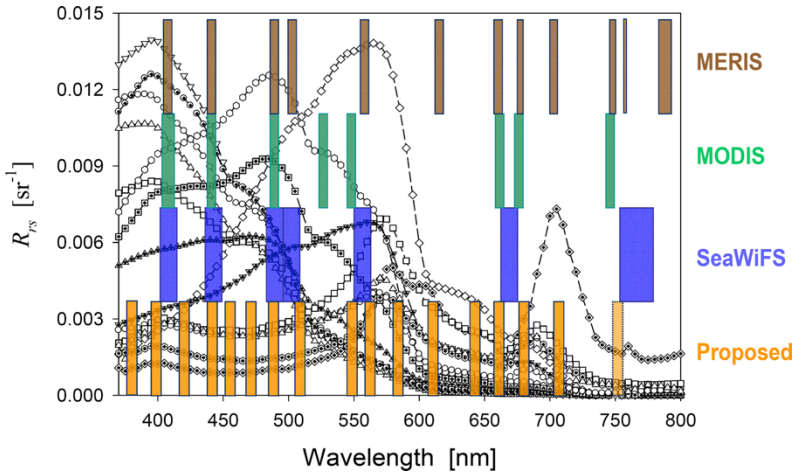
[+]Earth Observing-1
[*]NPP: Nation Polar Orbiting Partnership

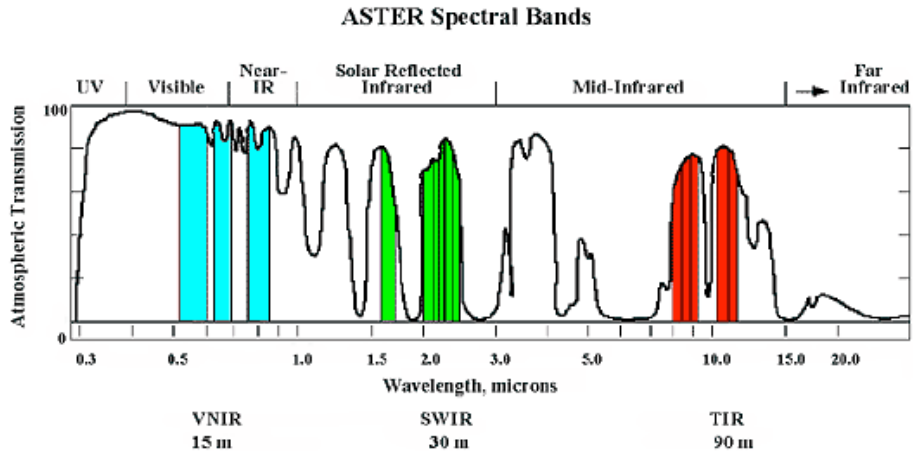
Spectral and Radiometric Resolutions

Spectral Resolution:
The number and width of spectral channels. More and finer spectral channels enable remote sensing of different parts of the atmosphere

Radiometric Resolution:
Remote sensing measurements represented as a series of digital numbers – the larger this number, the higher the radiometric resolution, and the sharper the imagery

Multi-spectral and Hyper-spectral Measurements

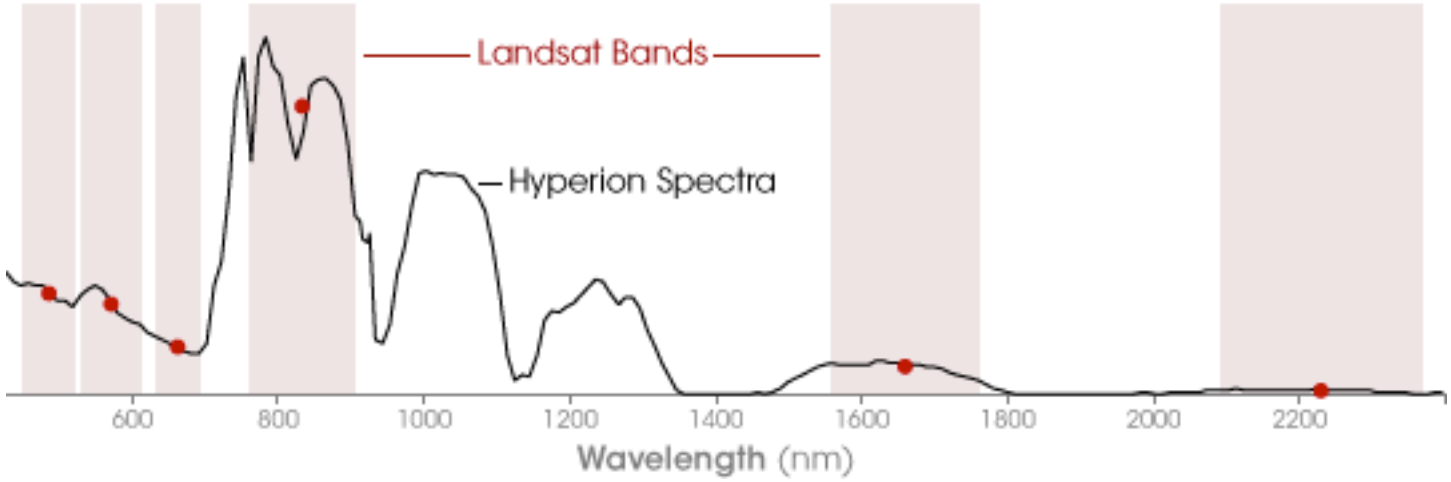




Lee et al., (http://spie.org/x18216.xml)

More Information in hyper-spectral images

http://www.ga.gov.au/scientific-topics/earth-obs/satellites-and-sensors/aster-radiometer



http:/earthobservatory.nasa.gov/features/

Current Remote Sensing Observations for WQ

Satellite	Sensor	Parameter
Terra Aqua	MODIS MODIS	Chlorophyll-a concentration, Temperature, Colored Dissolved Organic Matter (CDOM), Turbidity, Euphotic Depth[1]
Landsat	TM and ETM+ OLI	Spectral Reflectance
Terra	ASTER	Spectral reflectance, Temperature
NPP	VIIRS	Spectral Reflectance, Chlorophyll Concentration

MODIS: The Moderate Resolution Imaging Spectroradiometer
ASTER: The Advanced Spaceborne Thermal Emission and Reflection Radiometer
TM and ETM: Thematic Mapper and Enhanced Thematic Mapper **OLI:** Operational Land Imaging
VIIRS: Visible Infrared Imaging Radiometer Suit

[1]The euphotic depth is the depth at which light intensity falls to 1% of the value at the surface of a body of water. Euphotic depth is influenced by phytoplankton, colored dissolved organic matter, and suspended particulate matter.

Additional Remote Sensing Observations for WQ

	Satellite	Sensor	Parameter
Research Missions	EO-1	Hyperion ALI	Spectral Reflectance
	International Space Station	HICO	Spectral Reflectance (gathered upon request)
Past Missions	SeaStar	SeaWiFS	Chlorophyll-a, Temperature, Particulate Inorganic Carbon, Particulate Organic Carbon, CDOM Index
	Envisat (ESA)	MERIS	Spectral Reflectance, Chlorophyll concentration

ALI: Advanced Land Imager
SeaWiFS: Sea-viewing Wide Field-of-view Sensor
MERIS: MEdium-spectral Resolution Imaging Spectrometer
HICO: Hyper-spectral Images for Coastal Oceans

Remote Sensing Observations: Trade Offs

- It is very difficult to obtain extremely high spectral, spatial, temporal and radiometric resolution at the same time
- Several sensors can obtain global coverage every one to two days because of their wide swath width (Terra/Aqua)
- Higher spatial resolution polar orbiting satellites may take 8 – 16 days to attain global coverage (Landsat, EO-1)
- Large amount of data with varying formats
- Data applications may require additional *in situ* measurements, processing, visualization and other tools

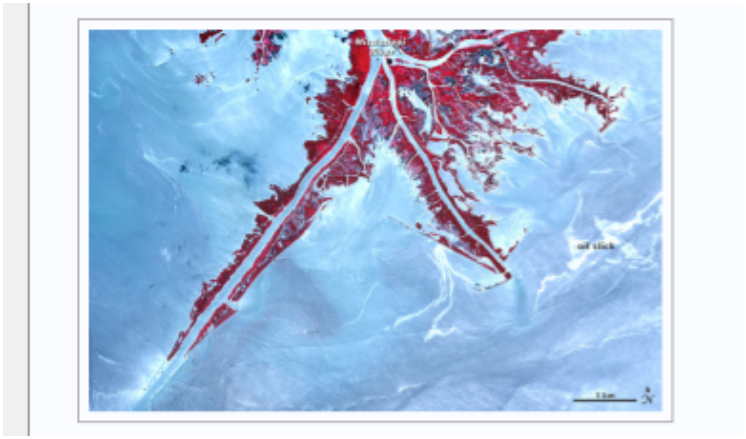
For water quality parameters:

- Spectral reflectance in the presence of clouds may be unsuitable to use
- Atmospheric contribution to the reflectance has to be corrected to get the surface water properties
- Medium-spectral bands data may contain effect of multiple WQ parameters
- In the coastal zones data may contain land contribution

Examples of Water Quality Monitoring with Remote Sensing

Observing Water Quality from Space

Terra/ASTER



ASTER image captured the Mississippi Delta and nearby polluted water (June 10, 2010). Vegetation in red, water in white blue and white

Nas et al. 2009: Environ Monit Asses, 157-275-382
DOI 10.1007/s10661-008-0542-9

With Landsat 8's improved ability to detect variations in colors, the waters of Lake Ontario can show sediment patterns as well as potentially problematic algae, indicated by higher chlorophyll concentrations. Image Credit: NASA/USGS

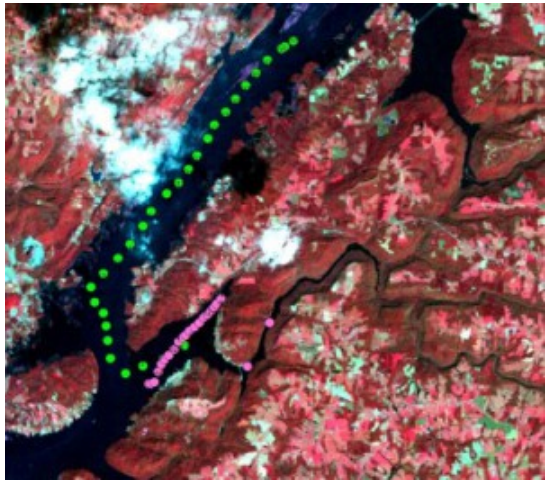
Observing Water Quality from Space

ASTER image captured the Algal Bloom that affected Lake Atitlan, Guatemala in 2009 (01 December 2009). Vegetation in green, clean water in deep blue.

More information NASA-SERVIR.
https://servirglobal.net/Global/Articles/tabid/86/Article/1082/reappearance-of-pollution-in-lake-atitln-solol-guatemala-may-2011.aspx

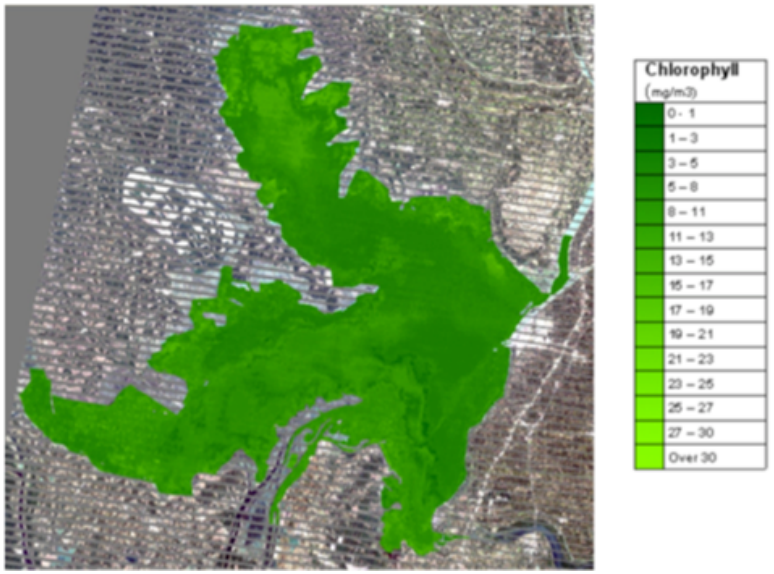
Observing Water Quality from Space

Landsat Applications



Landsat data (bands 4, 3, 2) were used with in-situ measurements to estimate the secchi disk depth of Guntersville Lake in Marshall County, Alabama. The pink points represent field data taken on Oct. 06, 2012 and the green points represent field data taken on the Oct. 21, 2012. Image Credit: DEVELOP Marshall Team

http://www.earthzine.org/2012/11/27/using-nasa-eos-to-monitor-water-quality-in-alabamas-lakes/



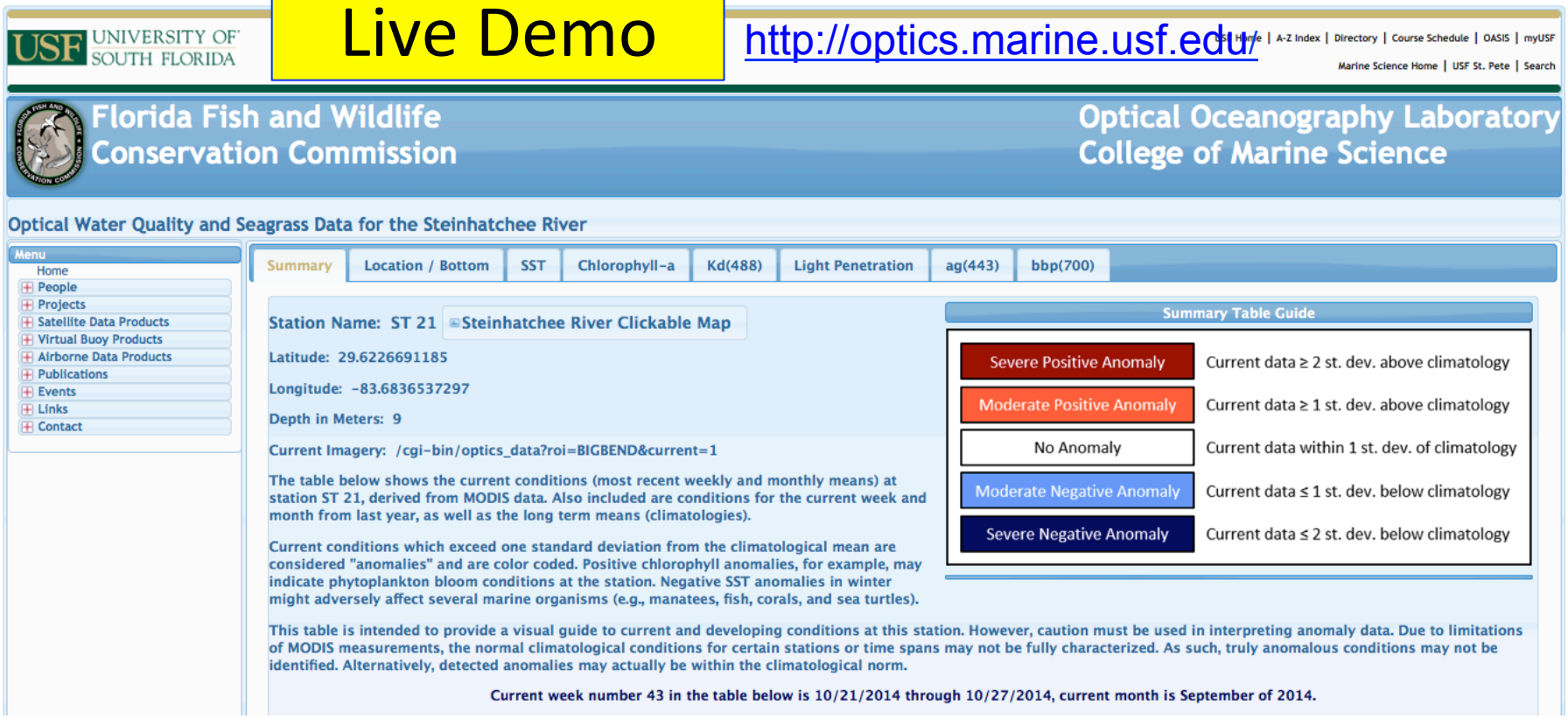
Landsat 7 Thematic Mapper image-derived suspended chlorophyll concentrations (mg/m3, or µg/l) in Hongze Lake, China (20 April 2004). The QSC Water Quality application retrieves the concentration of suspended total chlorophyll from each water pixel, yielding a compositional "map"

http://www.discover-aai.com/waterquality.htm

NASA-Funded Water Quality project

Enhancing estuarine water quality management through integrating earth science research results: A targeted project for Tampa Bay, Florida (C. Hu et al.)
https://docs.google.com/file/d/0BxTNwDBuMxoPQl9ESjJhOGVzVVE/edit

Live Demo http://optics.marine.usf.edu/



Courtesy: Duane Armstrong, NASA - Gulf of Mexico Initiative (GOMI)
http://gulfofmexicoinitiative.community.nasa.gov/

Coming Up Next Week (25 November 2014)

NASA WQ Data, Access, and Tools

- Data from Terra and Aqua/, Landsat, EO-1, NPP, satellites for WQ Remote Sensing
- Future Missions: GEO-CAPE, PACE, HyspIRI
- Tools to Access Data: SeaDAS, Giovanni, LP DAAC -- GloVis, EarthExplorer, LandsatLook, SEDAC
- Brief Overview of Models for WQ Monitoring

Thank You!

Amita Mehta **email:**